



Physical Sciences

Multi-Pass Quadrupole Mass Analyzer

The technology will enhance the resolving power of small QMA instruments and simplify the electronics package for ground and space instruments.

NASA's Jet Propulsion Laboratory, Pasadena, California

Analysis of the composition of planetary atmospheres is one of the most important and fundamental measurements in planetary robotic exploration. Quadrupole mass analyzers (QMAs) are the primary tool used to execute these investigations, but reductions in size of these instruments has sacrificed mass resolving power so that the best present-day QMA devices are still large, expensive, and do not deliver performance of laboratory instruments.

An ultra-high-resolution QMA was developed to resolve N_2^+/CO^+ by trapping ions in a linear trap quadrupole filter. Because N_2 and CO are resolved, gas chromatography columns used to separate species before analysis are eliminated, greatly simplifying gas analysis instrumentation. For highest performance, the ion trap mode is used. High-resolution (or narrow-band) mass selection is carried out in the central region, but near the DC electrodes at each end, RF/DC field settings are adjusted to allow broadband ion passage. This is to prevent ion loss during ion "reflection" at each end. Ions are created inside the trap so that low-energy particles are selected by low-voltage settings on the end electrodes. This is beneficial to good mass resolution since low-energy particles traverse many cycles of the RF filter-

ing fields. Through Monte Carlo simulations, it is shown that ions are reflected at each end many tens of times, each time being sent back through the central section of the quadrupole where ultrahigh mass filtering is carried out. An analyzer was produced with electrical length orders of magnitude longer than its physical length. Since the selector fields are sized as in conventional devices, the loss of sensitivity inherent in miniaturizing quadrupole instruments is avoided. The no-loss, multi-pass QMA architecture will improve mass resolution of planetary QMA instruments while reducing demands on the RF electronics for high-voltage/high-frequency production since ion transit time is no longer limited to a single pass. The QMA-based instrument will thus give way to substantial reductions of the mass of flight instruments. Advantages of the multi-pass quadrupole mass analyzer include:

- Provides ultra-high-resolution mass analysis to resolve N_2^+/CO^+ and Ne^+/Ar^{++} .
- Multiple passes through QMA region.
- Very slow ions can be created inside the trap compared to beam injection into conventional QMA.
- Low-risk, high-resolution performance sufficient to resolve N_2^+/CO^+ has already been demonstrated. This work will improve signal efficiency by 100-fold.

- Discovery, MIDEX, and all planetary science will advance by use of multi-pass QMA instrument development.
- Eliminates trade-off between high-voltage and high-frequency RF mass selector fields.
- Both high mass operation and high resolution are achievable in the multi-pass QMA.
- Mass range to over 1,000 Daltons will be provided.
- Recycling ion passage through mass selector fields, filtering length is orders of magnitude longer than physical length, matching resolution of the best ground-based instruments.
- This technique can be applied to improve mass resolution of ultra-miniature QMA devices.
- This approach reduces the risk and loss of resolution typically encountered in miniaturization of a quadrupole gas analyzer since the QMA device uses conventional-sized quadrupole filtering fields, acceptance angles, etc. as currently used in planetary instruments.

The pre-analysis provided by gas chromatography columns will not be required.

This work was done by John D. Prestage of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-47277

Lunar Sulfur Capture System

The process substantially reduces the need for Earth-supplied consumables.

John F. Kennedy Space Center, Florida

The Lunar Sulfur Capture System (LSCS) protects in situ resource utilization (ISRU) hardware from corrosion, and reduces contaminant levels in water condensed for electrolysis. The LSCS uses a lunar soil sorbent to trap over 98 percent of sulfur gases and about two-thirds of halide gases evolved during hydrogen reduction of lunar soils. LSCS soil sorbent is based on lunar minerals

containing iron and calcium compounds that trap sulfur and halide gas contaminants in a fixed-bed reactor held at temperatures between 250 and 400 °C, allowing moisture produced during reduction to pass through in vapor phase. Small amounts of Earth-based polishing sorbents consisting of zinc oxide and sodium aluminate are used to reduce contaminant concentrations to

one ppm or less. The preferred LSCS configuration employs lunar soil beneficiation to boost concentrations of reactive sorbent minerals.

Lunar soils contain sulfur in concentrations of about 0.1 percent, and halogen compounds including chlorine and fluorine in concentrations of about 0.01 percent. These contaminants are released as gases such as H_2S , COS , CS_2 ,